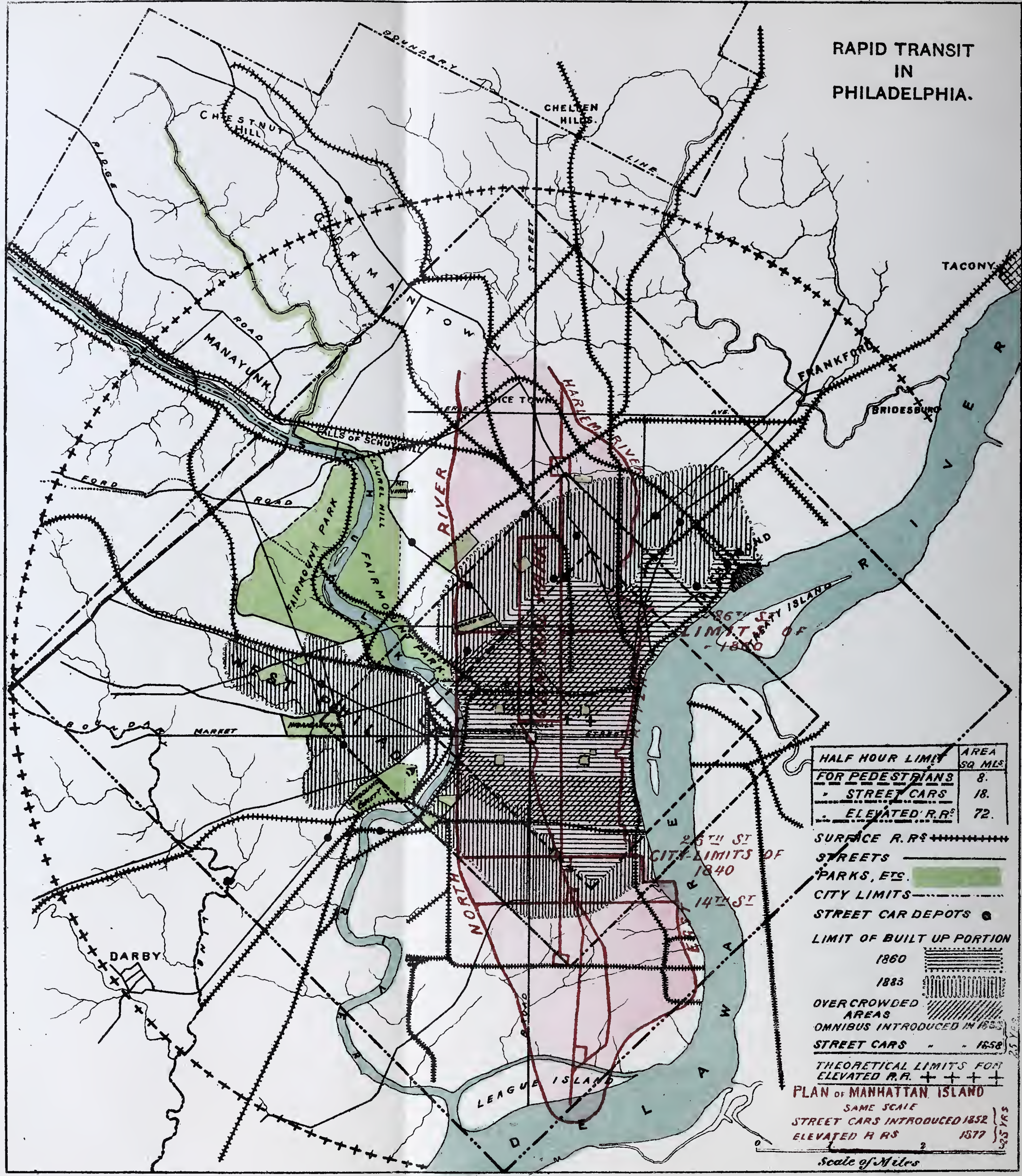
RAPID TRANSIT.

BY

PROF. L. M. HAUPT.


RAPID TRANSIT
IN
PHILADELPHIA.
BOUNDARY LINE
CHELTEN HILLS.
CHESTNUT HILL
RIDGE
GERMANTOWN
ROAD
MANAYUNK
STREET
TACONY
FRANKFORD
BRIDESBURG
FALLS OF SCHUYLKILL
FORD
ROAD
LAUREL HILL
FAIRMOUNT PARK
SCHUYLKILL
HARLEM RIVER
NORTH RIVER
EAST RIVER
86TH ST LIMIT OF 1860
PETTY ISLAND
WEST PHILADELPHIA
MARKET
STREET
BROADWAY
CENTRAL PARK
25TH ST CITY LIMITS OF 1840
14TH ST
DARBY
LEAGUE ISLAND
DELAWARE
RIVER
HALF HOUR LIMIT
AREA SQ MLS
FOR PEDESTRIANS 8.
STREET CARS 18.
ELEVATED R.RS 72.
SURFACE R.RS
STREETS
PARKS, ETC.
CITY LIMITS
STREET CAR DEPOTS ●
LIMIT OF BUILT UP PORTION
1860
1883
OVERCROWDED AREAS
OMNIBUS INTRODUCED IN 1833
STREET CARS - - 1858
25 YRS
THEORETICAL LIMITS FOR ELEVATED R.R. + + + +
PLAN OF MANHATTAN ISLAND
SAME SCALE
STREET CARS INTRODUCED 1852
ELEVATED R RS 1877
25 YRS
0
1
2
Scale of Miles

[*Extract from the Proceedings of the Engineers' Club of Philadelphia.*]

RAPID TRANSIT.

By Prof. L. M. Haupt, Member of the Club.

Read May 17th, 1884.

Gentlemen:

An article appeared quite recently in one of our local papers containing this statement: "The enormous growth of travel on city railways in New York, especially since the construction of elevated railroads, is little short of marvellous." This was followed by a quotation of statistics from the letter of John I. Davenport, Esq., dated March 29th, 1884, addressed to Mr. Melville C. Smith, President of the Broadway Underground Railway. As this letter is deserving of more than ordinary consideration, I desire to call your attention to a few of its prominent features and to draw some additional conclusions therefrom, with special reference to our own city.

Topography.

It considers first the topography of New York City or Manhattan Island, which is about nine and a half miles in length from Castle Garden to the Sixth Avenue crossing of the Harlem River, and about two miles in average width. The area within these limits, as measured by the planimeter, being 18¾ sq. miles. The island is surrounded by navigable rivers, which, with its water connections, extending as far west as Minnesota, have given it great commercial supremacy. Originally the surface was rugged and rocky, with numerous swampy depressions, which it has been difficult and expensive to grade and drain.

As the opponents of Rapid Transit in Philadelphia have made the *topography* of the two cities the main point in the arguments *pro* and *con*, it may not be amiss to compare the conditions. Philadelphia, like New York, is situated between two navigable rivers, but which, for the built up portion, are a little farther apart than are those of that city. Instead of being an island it is a peninsula. West Philadelphia, in its topography, may be compared to Brooklyn; and Camden to Jersey City. Both cities adjoin a foreign State. If a plan of Manhattan Island be laid over one of Philadelphia, drawn on the same scale, so that the Battery coincides with League Island, and Sixth Avenue with Broad Street, the Harlem River at Sixth Avenue (150th Street) will be found above Erie Avenue, and the whole of this part of New York will lie between these north and south limits and the two rivers, with about an equal area to spare. Or, if the plan of New York be shifted so as to bring the City Hall up to Market Street, the Battery will be found at Washington Avenue, and Fourteenth Street at Girard Avenue, whilst the Harlem will just touch the county line road. If then, there is a necessity for Rapid Transit in New York, there is a greater necessity for it in Philadelphia, for *its need is proportional to the extent of surface and the distance of the residents from the business centers.*

New Yorkers have the additional great advantage that their lines of communication are nearly all direct, whilst Philadelphians, in crossing the city diagonally, must be continually turning aside to go around the corner.

COMMERCIAL SUPREMACY.

Mr. Henry C. Gardner, in an address to real estate owners in New York, in 1870, said: "Commercial prosperity is secured and retained only by constant enterprise. Seventy years ago (1800) Philadelphia was the first commercial city on this continent. She contained a population of 70,287,* while that of her greatest rival was only 60,529. But New York added to the advantages of her harbor those of the Erie Canal, and thus secured the Western trade and with it commercial supremacy. For years she experienced the flood tide of success; but in 1860 the ebb began, since which time her decline has been far more rapid than her advancement.

POPULATION.

"Between 1800 and 1860 the increase of population in New York as compared with that of the United States was as 253 to

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* This was within the old city limits.

100, whilst from 1860 to 1870 the figures were reversed. In Brooklyn the population in 1860 was 266,661, and in 1870 it was 396,661, showing a gain of 130,000, which was 17,328 more than that of New York for the same period. The ratio of increase being as 48.75 per cent. to 13.84 per cent. In 1840 there were only 14,342 persons living above Fourteenth Street, when the city limits extended only to Twenty-sixth Street. In 1860 the population above Fourteenth Street had increased to 313,494, whilst that of the Third Ward, which is west of the City Hall, had decreased from 11,581 to 3,757, a loss of 7,724 or about 70 per cent.

Between 1840 and 1860 the total population increased 500,959 or 160 per cent., yet the Second and Third Wards decreased 187 per cent. The part above Fourteenth Street increased in these twenty years over 658 per cent. against 160 per cent. for the entire city. Street railways were introduced in 1852, and in 1860 there were six lines in operation, carrying for that year 36½ millions of passengers.

During the next five years six more lines were added, and in 1865 these twelve lines carried over 82 millions of passengers, yet the movement was confined to the old limits at Eighty-sixth Street, and during the next five years no additional lines were built, although the patronage in 1870 exceeded 115 millions.

The ratio of increase of population for the sixty years prior to 1860 was 28 per cent. every five years, 5.6 per cent. a year, which, had it remained constant until 1870, would have given a population then of 1,334,973, an increase of 520,404, whereas the actual increase was only 112,672, showing a loss of 407,732, a population greater than that of the city of Brooklyn, all of which would have been located in the upper part of the city but for lack of transportation facilities. The mere pecuniary loss to the real estate interests from this cause is estimated at $500,000,000, the revenues from which, @ 2 per cent., would have been $10,000,000.

Time Limits of Travel in New York.

Thus it is seen that up to 1860 New York increased rapidly in wealth and population, when she outgrew her limits and overflowed into Brooklyn and New Jersey, the stages and street cars being incapable of making better time and thus extending their distances. The limit of travel, as measured by time and convenience, in New York was then about four miles, and the business centre being at Wall Street, made it more expeditious and certain to reside even at some distance across the rivers than at the upper end of the island. Measured by time alone Harlem was 34 miles from the City Hall and Elizabeth, N. J., but 14. The convenience and certainty of travel by steam roads as contrasted with the sufferings and delays by the horse cars, in winter especially, placed an effectual barrier across the northward current and diverted it into the eastern and western channels.

DENSITY AND DISTRIBUTION OF POPULATION.

"In 1860 the population of New York was 813,669, of which number 468,549 or 57.6 per cent. resided below Fourteenth Street, in a district covering but 3¾ sq. miles of the 38.11 included in city limits. In 1870 the population was 942,292, of whom 497,289 or 52.8 per cent., a little more than half, lived within the above limits; and in 1880, of 1,206,299 persons only 542,251 or 45 per cent., considerably less than half, remained in the aforesaid district. This diminution of 12.6 per cent. shows the combined relief afforded by the surface and elevated roads to this densely populated district, and is its own commentary on the inadequacy of the provision. New York waited too long for relief.

In December, 1864, a census of New York showed 495,592 persons in 111,000 families (4½ to a family) living in 15,309 tenements and cellars. An average of 32.37 persons or 7¼ families to a house. Again in 1869 there were 483,492 persons in 113,405 families occupying 14,872 tenements, an average of 31½ persons to a house, and very nearly the same condition was found to exist in 1880, when there was an average of 31 to each tenement.

In Philadelphia, in 1870, there were 674,022 persons housed in 112,366 dwellings, giving 6 to each house. In 1860 the number was 6.3 to each house, and in 1880, 5.8. Here there are two extreme cases to which it may be said the same rule will not apply, but we will see on examination that it does, for "It's a poor rule that won't work both ways." New York is so densely inhabited not because it has no Rapid Transit facilities, but because they are wholly inadequate to provide for the wants of the community; it needs more for the health and morality of its citizens, and Philadelphia with her 910,707[*] inhabitants, spread out over 129.3 square miles of area, needs them for concentration and economy of time and energy. It is a question of time *vs.* health, for if our facilities of transit do not keep pace with our increase of population we will soon be corralled by time limits, and the density, mortality and immorality of the population must increase correspondingly. In New York 75 per cent. of all the deaths occur in the tenement houses or hospitals, where in some wards, notably the Tenth, Eleventh, Thirteenth, Fourteenth and Seventeenth, the population ranges from 432, 353, 349, 314 to 309 to the acre, while the best authorities place the maximum density compatible with health at 100 to the acre.

In Philadelphia, in 1880, the Third Ward was peopled at the rate of 150 to the acre, and the Fourteenth was nearly as dense. The Fourth, Seventeenth, Twelfth, Thirteenth, Seventh and Tenth are all above the maximum limit (in the order given). These wards lie south of Pine Street and north of Vine, as stated in a previous paper on Intercommunications in Cities (Vol. II, 1881), where the subject of the distribution of the population is more fully treated, and some important deductions given, which need not now be repeated. It will be sufficient to indicate these overcrowded zones by a shade on the map, thus exhibiting their relative positions and extent, and showing where relief is desired.

Theoretical Consideration of the Relative Rates of Travel, Whether on Foot, by Street Cars, by Elevated or Underground Roads, or by Ordinary Surface Railroads, as Affecting the Areas Available for a Salubrious Distribution of Population.

As the velocities of travel are equal to the distances divided by the times, or $v = \frac{d}{t}$, let us assume a uniform value for t, variable values for v and determine the resulting values for d, and, as a fair basis of comparison, let us make *the time limit a half hour,* as being the average time which the business or laboring classes of a community require in going to, or in returning from, their occupations. The value of t will then be 30 minutes. In this time and at the ordinary velocities the distances traversed will be:

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[*] Estimated for 1883.

	Miles.		Min.
For pedestrians,…………	2	or at the rate of one mile in	15
" horse cars, " cable system, ………	3	" " " "	10
" elevated, ……………	6	" " " "	5
" underground or way trains, ………	10	" " " "	3

It will probably meet the case fully to assume that each person traveling by any of the above means moves over the entire distance, that is, that a pedestrian makes a round trip of 4 miles from the perimeter to the business centre and back; hence the limits of a city where the residents go on foot would have a radius of *two miles* or an area of 12½ square miles if people could move across it radially.

Under similar conditions the street car or cable city would be limited by a radius of *three miles* or an area of 28¼ sq. miles; the elevated railroad city of *six miles* with an area of 113.04 sq. miles, or *four times that of the street car*, and the underground railroad city a radius of *ten miles* or an area of 314 sq. miles. These theoretical limits, except the last, are shown on the map by the several circles described from Sixth and Market Streets as a business centre.

Practically, however, as there are no radial streets in the greater portion of these areas, and passengers are thus compelled to zigzag across the city diagonally, the areas will become squares with their diagonals on the principal axes, and the practical limits will be as follows:

Pedestrians,………	diag. 4	miles,	area 8.00	sq. miles.
Horse or cable, …	" 6	"	" 18.00	"
Elevated,…………	" 12	"	" 72.00	"
Underground,……	" 20	"	" 200.00	"

whilst the total area of the city is 129.3 sq. miles.

With the business centre at Sixth and Market Streets however, the plan of *this* city does not admit of unlimited expansion in all directions, as the Delaware River will cut off the eastern angles of the squares, thus reducing the practically available areas to about 6¾ sq. miles or 5 per cent. of the whole area for pedestrians;* 13½ sq. miles or 10½ per cent. for street cars, and 50 sq. miles or 44 per cent. of the entire area for elevated roads. The extent of these limits will be more clearly illustrated by reference to Plate I. From the above data it is evident that a rate of travel of 6 miles per hour is *altogether inadequate* to render available the territory of a city having an area of 129 sq. miles.

VERIFICATION.

To verify the above assumptions as to position and distances the present limit of the built up portion of the city has been indicated on the map, from information furnished by the Registry Department, and by comparing it with the square representing the street car city, it will be seen that the half hour limits of street car travel have already been reached and in some instances passed, and that the depots and stables are close to these limits, being generally inside.

Where there are diagonal avenues, as in the case of Ridge, Lancaster and Woodland Avenues, and the oblique streets in the northeastern section of the city, the improvements have slightly surpassed the limits, proving conclusively the effect of a reduction of time and distance in extending and rendering more valuable the taxable property of the city.

In the southern portion the buildings have not yet quite reached the street car limit, but as the residents are chiefly artisans and the manufacturing centre is north of Vine Street, this would bring them to the half hour limit from their center of occupations. But irrespective of these limits, as determined by linear distances from a centre, let us compare the *areas*. We have found the theoretical street car city to contain 13½ miles or

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* The actual area of the built-up part of the city at the date of the introduction of street cars 1858–59 was 7 square miles and the limits are found to concide very closely with the theoretical square above given, thus further corroborating the correctness of the assumed data. The centre of the built-up city is at Sixth and Cherry Streets and not at Sixth and Market Streets.

8,640 acres. The built up city as measured by a planimeter, excluding Fairmount Park, Woodland, Pennsylvania Hospital for Insane and the Almshouse grounds and Schuylkill River, contains about 16 square miles or 10,108 acres, leaving an excess over the street car city of 1,468 acres, located in the salients bordering the diagonal avenues previously mentioned. A part of this area is accommodated by the various railroads entering the city, but they cannot be regarded as fulfilling the requirements of rapid transit for a local or resident population, as the local trains are run at too long intervals, stations are too far apart and fares too high.

If it be true, as shown above, that *the city has surpassed her limits of travel by street cars,* then there should be a diminution in the percentage of increase in population and an overflowing in the direction of least resistance or to that portion most available and nearest in point of time. Let us see what the statistics have to say.

CENSUS OF PHILADELPHIA CITY AND COUNTY.

Year.	Population.	Increase.	Rate.
1800	81,009	-	
1810	111,210	30,201	37.3
1820	135,637	24,427	22.0
1830	188,797	53,160	39.2
1840	258,037	69,240	36.5
1850	408,762	150,725	58.5
1860	565,529	156,767	38.5
1870	674,022	108,493	19.3
1880	847,170	173,148	25.7

Here is a marked and rapid decline in the ratio of growth from 5.9 per cent. per annum in the decade ending 1850, to 2.5 per cent. in that ending 1880. Had the ratio of 1850 remained constant for these thirty years the population should have numbered 1,124,095, instead of 847,170, being a loss of 276,925 persons with all that it entails. Yet this additional population could not be housed in the present city without greatly endangering the health and welfare of the community and reducing it to the deplorable condition of the tenement districts of New York, which are a disgrace to our civilization. Will any one say that this "City of Homes" has reached the limits of a ripe old age and must now decline in her senility for want of more rapid communications?

Again, if Philadelphia has reached the limit of growth by street cars, and there be an available spot for habitation outside of the city but within the time limit we have assumed, we must look there for an increase of population. To cross the Delaware River requires from five to eight minutes, and the boats run at intervals of seven minutes. Thus, in an extreme case, it may take fifteen minutes to cross the river; this is equivalent to one mile on foot, or one and a half in street cars, leaving a half mile more available for pedestrians and over a mile for those who ride to the ferry on the Camden side. We would then expect Camden to receive a large portion of the overflow. What are the facts?

The population from 1850 to 1880 is as follows:

Years.	Population.	Differences.	Per cent. increase in decade.
1850	9,479		
1860	14,358	4,879	51 per cent.
1870	20,045	5,689	40 "
1880	41,659	21,604	108 "

And it is believed that the ratio of increase since 1880 is even greater than 10.8 per cent. per annum.

Does Philadelphia desire to drive her population into an adjoining state?

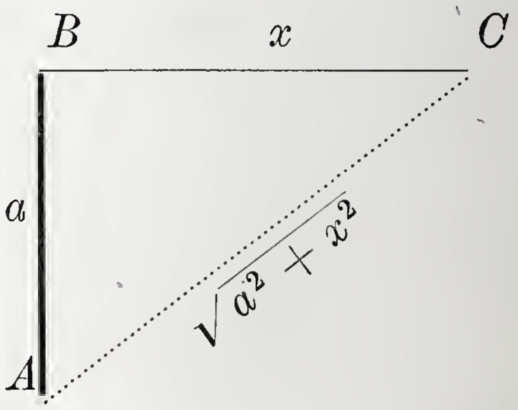
In West Philadelphia the increase is as follows:

Year.	Population.	Increase.	Rate.	
1850	5,571	Before Consolidation of City in 1854.		
1860	23,738	18,167	326.	24th Ward.
1870	43,571	19,833	84.	24th and 27th Wards.
1880	69,341	25,770	59.	

The available space in West Philadelphia is the narrow strip between the Penna. R. R. and Woodland Avenue, hence the crowding out beyond time limits and the rapid decline in the ratio of growth.

ELEVATED ROADS.

We have already shown that if the velocity of travel be increased to that of elevated roads, the area, within the half hour limit, would equal three times that of the present built up city, but since it is impossible to have such roads pass every door, we will confine our attention to two lines, running at right angles to each other through the same business centre, viz., Sixth and Market Streets. And here we are met by the query: Of what use would such lines be to the majority of citizens? The question resolves itself into this: How far from the "L" road may a person live so as to be able to save time by patronizing it rather than by walking in a straight line to his objective point, were that possible?



Let AB represent the line of railroad and C the residence of a citizen who must walk a distance x and ride a to reach A, or else, if possible, walk a distance $= \sqrt{a^2 + x^2}$. As the times of travel by the two routes must be equal for the outer limit and the velocities on x and a are unequal, we have the equation $\frac{x}{v} + \frac{a}{v'} = \frac{\sqrt{a^2 + x^2}}{v}$ in which v is the rate on foot and v' by the elevated road. This gives $x = \frac{a}{2r}(r^2 - 1)$, r being $= \frac{v'}{v}$ = ratio of velocities. If then $r = 3$ as it is in this case, x will be equal to $\frac{4a}{3}$; or $1\frac{1}{3}$ times the distance traveled on the railroad would be the distance one might walk to use it, if the time limit be made indefinite or unlimited. Thus the whole area of the city would be benefited by an L road and the sectors of tributary area would overlap. The central angle of this sector being 106° 16′, the four angles would give 425°, or a total overlapping of 65°, which, in the absence of diagonals for walking, should more than equal the loss of time in making connections. For horse cars the locus of equal time intervals would be $\frac{5}{12}$ a, or nearly half mile on foot to a mile by street car, and for way trains on railroads the distance is $\frac{12}{5}$ a, or the reciprocal of that by horse car travel.

But as we have limited our distances to a half hour of travel, it is evident that this limit is reached at a point *on* the elevated road at six miles from the centre, and hence at that distance the citizen must live on the line of the road, while, if he walk at all, his distance from the line must not exceed that given by the formula $x = \frac{6 - a}{3}$ where a is the length of that portion of the elevated road used, measured from the center.

From this formula when a is zero, x will be two miles, and when x is zero a will be six miles. Straight lines joining these points will then give the perimeter of the half hour limit and will show the total available area tributary to the road within this time limit. This enclosed area is equal to 36 square miles for these two lines of railroad, but as the eastern salient will lie over the river it should be deducted, leaving about 30 square miles, or 19,200 acres as the tributary area*, and if the population be put at the healthful limit of 100 to the acre, the total population in this area would be 1,920,000, and if the annual patronage were only ten† times the total population, it would reach the large aggregate of 19,200,000 passengers for these two lines.

In New York the number of passengers carried on all lines in 1883 was 200 times the total population, that by the four elevated roads being 70 times, and so great is the need for more rapid transit that a bill authorizing the construction of the Broadway Underground Railway has passed the legislature, and the company is preparing to push the work vigorously. It is proposed to lay four tracks, two for through and two for way trains, the first to run from the Battery to 130th street in 17 minutes, or to High Bridge in 22 minutes and the north line of the city in 34, with but few stops, while the other would run more slowly and stop more frequently. The proposed capacity will be a million passengers a day, and it will carry freight at night.*

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* The present built up area is 16 square miles.

† In New York the average is 17½ times.

Boston, too, has just authorized the construction of a new form of elevated road for more rapid travel to Cambridge, and it is hoped that the request recently made of this city to grant the right to construct an "L" road in the northeastern section thereof, will receive prompt attention.

If the 2½ per cent. increase of population in Philadelphia has remained constant during the past three years, the present population would be 910,707, whilst the estimated total street car travel is 110,644,571. Thus the ratio of travel to population is as 121 to 1. The travel here is divided between 17 lines, giving an average of about 6½ millions to each line. In New York it is 7⅔ millions.

As most of the opposition to the elevated roads is supposed to come from property owners along the routes, or from parties interested in surface roads, it may be reassuring to state that the effect of the improvements in New York has been generally greatly to enhance the values of properties on the line as places of business, and but temporarily to reduce the travel on the horse car lines, which in 1878, when the "L" roads began operations, were carrying about 161 millions, and in 1883 the same surface roads conveyed 176½ millions, an increase of 15½ millions. In addition to this the elevated roads have created a business in five years of over 92 millions of passengers, chiefly because of their increased facilities, and have kept people in New York who would otherwise have gone over the rivers. The *net* increase in valuation of real estate in New York for four years *prior* to the opening of the elevated roads, as given by the annual reports of the Tax Commissioner, was 21,363,680, while for the four subsequent years it was 134,348,616, an increase in four years of about 123 millions.

The elevated roads occupy an intermediate position in cost of construction, rate of travel and general utility between surface and underground structures, and there can be no doubt whatever that the time has fully arrived when this city, *for her own sake,* requires them, and should heartily cöoperate with any parties so proposing to improve and extend her resources.

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* Since writing the above, we learn that the bill was vetoed by the Governor.

It is not within the province of this paper to indicate either the location of or the form of "plant" best adapted to subserve these ends, but merely to urge the importance of providing the means to obtain them, and thus to promote the general welfare of the city and encourage its growth.

From these data and arguments we are led to the following conclusions:

1. The city has reached and already surpassed the ordinary limits of street car travel.

2. The ratio of increase of population is declining, chiefly from lack of more rapid and cheaper means of transit.

3. The present steam roads in the city cannot supply the demand as they are SURFACE lines; trains must move slowly and cannot be run at close intervals, fares are too high and stations too distant.

4. Camden, New Jersey, is rapidly gaining at the expense of Philadelphia.

5. The annual loss to the city in revenue from this cause will reach millions of dollars.

6. Unless relief is provided the density of the population must rapidly increase at the expense of health and morality.

7. Two lines of elevated railroads at right angles to one another and properly located, would benefit an area equal to double that of the built up portion of the city.

8. The fears of the opponents of elevated roads of losses to the city or the individual, from withdrawal of patronage or depreciation of property, are shown by experience in New York to be groundless.

9. If Philadelphia desires to retain even the present low rate of increase in population and high rate of salubrity, she must promptly respond favorably to the request of her citizens to be permitted to build elevated roads.

10. The limits of the city are not such as to warrant any corporation in building an *underground* road, were it allowed, with any fair prospect of returns for many years.

ADDENDA.

A local paper, issued May 21st, contained this statement: "There is an average of 843 people to an acre living in New York City."

This error was probably derived from a table published with the letter of Mr. Davenport, previously cited, where, under the head of "Population to the acre," occur the figures 841.16, but a closer inspection shows that they are on the horizontal line opposite the words: "Average to the block," and the block contains an average of 2.98 acres, which would make the population to the acre 282.3 instead of 843. This, moreover, is exclusive of the streets, parks, etc. The correct exhibit is given on page 6 of said letter, as follows:

"In the year 1880, including all the parks, streets and the comparatively uninhabited annexed district, the City of New York contained an average of 49.95 persons to the acre. * * Omitting that portion of Westchester County annexed to the city in 1874 and the Park, we find the average population to the acre on Manhattan Island in the year 1880 to have been 109.66 individuals" (to the acre). This is but an average of 9.66 above the health limit.

In Philadelphia between the Second and Seventh Wards on the south and the Eighteenth, Nineteenth and Twenty-ninth on the north, all included, the total population in 1880 was 490,443, and the total area between the rivers 5,829 acres, giving an average of 84.14 persons to the acre, which is 4.14 higher than the maximum limit as fixed by the best *English* authorities. Throughout this paper we have taken the French limit of 100 as our unit.